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Availability of Lead, Zinc, Copper, and Cadmium to the Peregrine Falcon (Falco peregrinus) from Waterfowl of the Craney Island Disposal Area

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AVAILABILITY OF LEAD, ZINC, COPPER AND CADMIUM TO THE PEREGRINE FALCON (*FALCO PEREGRINUS*) FROM WATERFOWL OF THE CRANEY ISLAND DISPOSAL AREA

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To

Mitchell A. Byrd,

My Family

and to

John Whipp Davis

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ABSTRACT

The Craney Island Disposal Area is a large confined dredged spoil disposal site in southeastern Virginia. For 30 years dredged material from the Elizabeth River and Hampton Roads has been deposited there. These dredged sediments are known to be contaminated with a variety of environmental pollutants including heavy metals. Some heavy metals have been shown to bio-accumulate in aquatic food chains and to produce toxic effects on bird-life.

Rain water and water from hydraulic dredging operations create large shallow ponds at the disposal area. Some of these ponds support large populations of invertebrates. Attracted by this forage base, waterfowl and shorebirds often use the site in great numbers. Peregrine falcons (*Falco peregrinus*) also make significant use of the disposal area, apparently attracted by the waterfowl and shorebird prey base and by the open expanse of the site. With the peregrine falcon at the top of a potentially contaminated food chain, the possibility of heavy metal poisoning must be considered.

To determine if peregrine falcons foraging at the Craney Island Disposal Area are at an increased risk of heavy metal poisoning, livers from two falcon forage species were analyzed for lead, zinc, copper and cadmium. Metal values from liver analysis of 23 ducks from the disposal area and 6 ducks from a control group were compared to metal values in the literature. Single tail t-tests for significance were performed.

The data indicate that peregrine falcons foraging at the disposal area appear to be at no greater risk (and possibly at a lesser risk) of the bio-accumulation of lead, zinc, copper and cadmium than falcons foraging elsewhere.

AVAILABILITY OF

LEAD, ZINC, COPPER AND CADMIUM

TO THE PEREGRINE FALCON (*FALCON PEREGRINUS*)

FROM WATERFOWL OF THE

CRANEY ISLAND DISPOSAL AREA

INTRODUCTION

The purpose of this study is to determine if peregrine falcons (*Falco peregrinus*) foraging at the Craney Island Disposal Area (CIDA) are at a greater risk of bio-accumulation of lead, zinc, copper and cadmium than peregrines foraging elsewhere. Since the peregrine falcon is on the Federal Endangered Species list, any environmental contaminant which could adversely impact the species is of concern.

The Craney Island Disposal Area is a 2500 acre (1012 hectare) confined dredge spoil disposal site located in southeastern Virginia near the city of Norfolk (Fig. 1). The disposal area is operated by the Norfolk District of the U.S. Army Corps of Engineers. Spoil is contained by earthen dikes. The site is roughly square in shape and has a perimeter of approximately seven miles (11.2km). Since its construction in the mid 1950's more than 130 million cubic yards (99.3 million cubic meters) of dredged material has been deposited at the site. Nearly all of this material was dredged from the channels and ports in the Hampton Roads area and the Elizabeth River (Palermo, et al, 1981).

Heavy industry has dominated much of the shoreline of Hampton Roads and the Elizabeth River for decades (Virginia State Water Control Board, 1984). Partly as a result of the highly industrialized nature of the land use surrounding Hampton Roads and the Elizabeth River, much of the bottom sediment in these waterways is highly contaminated by a variety of environmental pollutants.

In the Elizabeth River, lead, zinc, copper and cadmium levels within the water column are above or near EPA's 1980 criteria for chronic toxicity to saltwater aquatic life (VSWCB, 1984). Elevated levels of these metals have been found in Elizabeth River sediments. Overall metal levels in the river sediments are from 2 to 10 times greater than those in mid-Chesapeake Bay sediments and much greater than levels typically found within the earth's crust (Environmental Protection Agency, 1976). Table I gives metal values from sediments from the Elizabeth River and from the Chesapeake Bay and ranges of values found within the earth's crust (EPA, 1976). It is these contaminated river sediments which have been deposited in the disposal area.

Rainwater and water from hydraulic dredging operations often create large ponds within the disposal site. These ponds frequently support large invertebrate populations and attract waterfowl and shorebirds in great numbers which feed on the invertebrates. Because of this, the disposal site is known among local birdwatchers as a premier area for viewing these birds. This concentration of waterfowl and shorebirds provides an ideal prey base for peregrine falcons (Bent, 1938; Sherrod, 1978; Cade, 1982). Numbers of observers have reported peregrine falcon use of the site (see discussion section).

With highly contaminated sediments within the disposal area, the potential hazards of heavy metal accumulation and poisoning in falcons using the site must be considered. These environmental contaminants could impact migratory and wintering peregrines as well as the small resident population of coastal Virginia which has been established by reintroduction efforts.

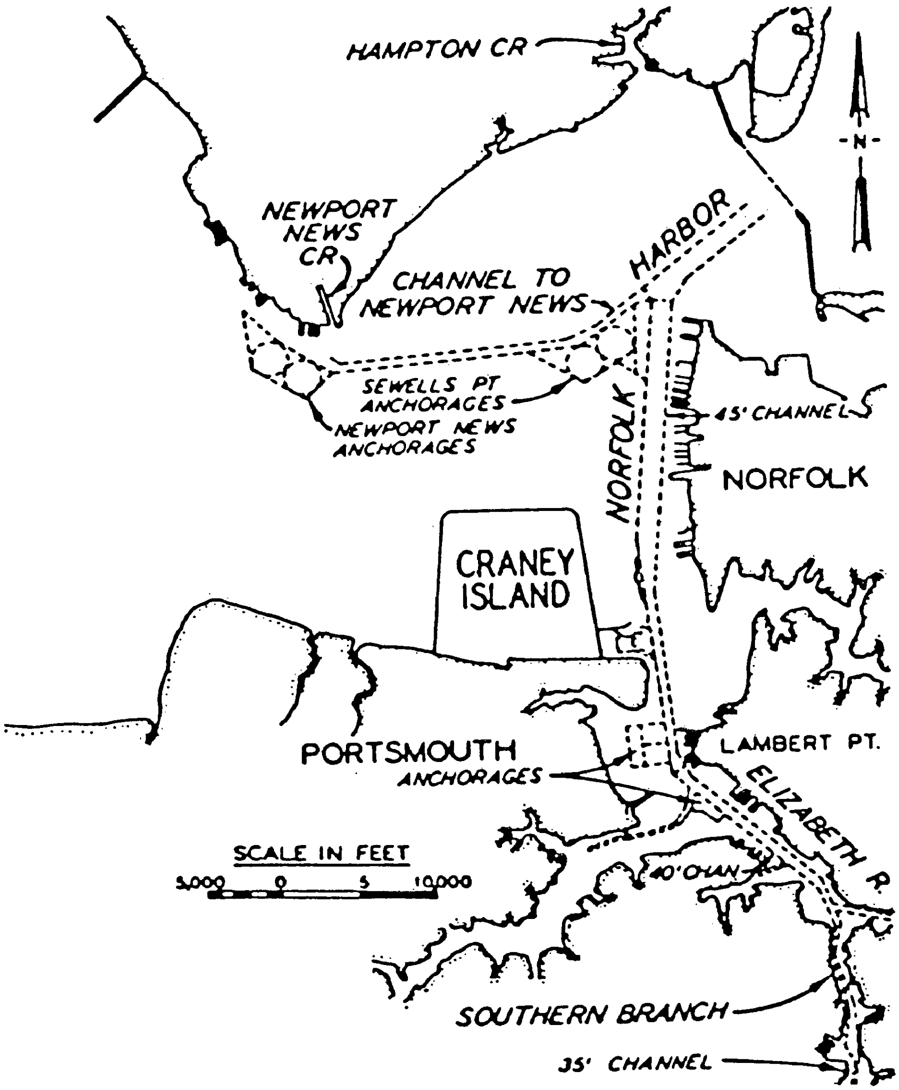

Figure 1. Craney Island Disposal Area

After Palermo, 1981

METHODS AND MATERIALS

Concentrations of lead, zinc, copper and cadmium in the livers of two peregrine falcon prey species were determined in the present study.

Twenty-nine ducks were collected and their livers analyzed for these metals. As part of this total, a flock of ten mallards (*Anas platyrhynchos*) was raised specifically for the present experiment. In addition, twelve wild mallards and seven wild northern shovelers (*Spatula clypeata*) were collected within the disposal area.

The ten 3-day old mallards were raised to 67 days of age. The ducklings were first kept in a covered wire cage for protection from the weather and predators. They were transferred to an enclosed outdoor pool when approximately 2 weeks old. Commercial duck mash and clean water were supplied *ad libitum*. In late June of 1984, at 67 days of age, the ducklings were color banded for individual identification and randomly divided into two groups. One group of six mallards was placed in a lake at Northwest River Park in Chesapeake, Virginia to act as a control. The lake is isolated and was excavated from virgin earth in the early 1970's. Prior to excavation the lake site and nearly all of the 763 acre park was forested and was subject to infrequent human use. Drainage into the lake is from the surrounding park which is still mainly forested. For these reasons, the lake is assumed to be free of heavy metal contamination (beyond ambient levels). The other group of four mallards was placed in a small pond (approximately 2 acres) in the disposal area. The specific pond was chosen because it supported an extensive invertebrate community and was a known foraging site for wild waterfowl and shorebirds. The site was also considered to be representative of forage sites within the disposal area. Both groups of ducks were periodically observed at their respective release sites until they were collected. Observations revealed that both groups were foraging well and growing at an appropriate rate until collected (Bellrose, 1976). No evidence of unusual behavior or outward physiological or morphological disorders were noted during this period.

All of the shovelers and 18 of the mallards were collected with a shotgun using steel shot. Steel shot was chosen over lead shot to prevent the possibility of contamination of any of the sample ducks with lead from shot pellets. The remaining four mallards were botulism poisoning casualties at CIDA and were simply picked up beside the pond where they had died or were dying (more information on the botulism poisoning is provided in the results section). Shovelers were collected from the disposal area during late winter. For four weeks prior to collection, general flock behaviors, feeding sites and schedules, and flock compositions were monitored. In monitoring flock compositions the size of the flocks, sex ratios within flocks and stage of molt of some of the males were noted. General observations of waterfowl were made from mid-fall through January. These qualitative observations indicated that the shovelers collected were probably residents for at least four weeks before collecting and likely residents from early winter until collection in late January. All shovelers were observed to be actively foraging prior to being collected. Immediately after collection the crops of six of the shovelers were opened and the contents placed in plastic sample bags and then frozen for later identification. The crop of the seventh shoveler was not opened in order to keep that bird's skin intact for use as a study skin. This duck was used, however, in liver analysis. After collection (and removal of the crop contents of the six aforementioned shovelers) all ducks were frozen whole for dissection and analysis.

Dissections were made with acid washed stainless steel instruments on a plastic dissecting tray. All glassware was prepared for use with a detergent wash, a deionized water wash and then an acid wash. The acid wash for the above dissecting equipment and glassware was HNO_3:HCL:H_2O prepared at a ratio of 1:1:6. A single undamaged liver lobe was removed from each duck, weighed to the nearest tenth of a gram and placed in a numbered tared beaker. Each liver section was then oven-dried in its beaker at 103°C for 40 hours. Livers were ashed in a muffle furnace at 450°C for one hour.

The resulting ash was then digested in a solution of HNO_3:HCL:H_2O at a ratio of 1:1:6. After a period of 1 to 4 days the contents of the beakers were transferred to clean centrifuge tubes and centrifuged at 2000 RPM for 5 minutes. The liquid fraction was filtered through glass wool to remove any remaining solids. The resulting supernatant was collected in clean plastic vials.

Wet weight concentrations of lead, zinc, copper and cadmium were determined in the supernatant by atomic absorption spectrophotometry. Analysis of Pb, Cu and Cd was performed on a Perkin-Elmer 703, electrically heated graphite furnace spectrophotometer. Zn was done on a Varian Techtron, air-acetylene flame, single flume, AA-spectrophotometer. The spectrophotometers were set at the following wavelengths for the specified metals: Pb, 217.0

nm; Cu, 324.7 nm; Cd 228.8 nm; Zn, 213.9 nm. To insure accuracy, blank samples and prepared certified standard solutions of known metal concentrations (supplied by Fisher Scientific Co.) were run before, after and at random intervals during the experimental sample runs. The above analytical procedure is taken from DiGuilio (1982).

Metal concentrations obtained in this study were compared to those reported in the literature for prey species from elsewhere and to control values. A statistical analysis was performed using a single-tail t-test for significance. The tests were performed using the method for a "Test of equality of means of two samples whose variances are assumed to be unequal" (Sokal and Rolfe, 1969). Sample variances for literature values were calculated from the standard error of the means as reported. Some of the literature values were reported in ppm/wet weight. In order to generate data compatible with the dry weight values of the present study these reported wet weight values were scaled by the factor 2.95 (Scanlon, unpublished data in DiGuilio, 1982) and statistics were then generated. Scanlon compared wet weight/dry weight percents for mallard livers. Using Scanlon's findings, dry weight metal values were determined by multiplying wet weight metal values by 2.95. Conversely, wet weight values were calculated by dividing dry weight values by

2.95. Care must be taken not to confuse the above conversion procedure which deals with metal values or concentrations with the inversely proportional procedure of converting a sample's dry weight to it's wet weight (such as converting the dry weight of a duck liver sample to it's wet weight). In this procedure the dry weight of a sample is multiplied by 2.95 to calculate the wet weight of that sample. Conversely, the wet weight of a sample is divided by 2.95 to determine its' dry weight.

Ponds at the disposal area were sampled for macro-invertebrates with a small dip net. The net mesh was approximately .03 inch (.75 mm) and the mouth of the net approximately 4 inches by 6 inches (10 cm x 15 cm). The ponds were randomly sampled for macro-invertebrates in January, March, April, June and July of 1984. Macro-invertebrates were identified and counted under a dissecting scope at powers ranging from 10x to 25x. Micro-invertebrates are not addressed in this study.

Peregrine falcon use of the CIDA was determined by questioning ten local ornithologists regarding their field observations. Six of these individuals responded in writing to a questionnaire and four responded verbally.

RESULTS

To determine if heavy metal bio-accumulation from CIDA is indeed a threat to peregrine falcons, 23 waterfowl were collected from the disposal area to serve as experimental ducks and six were collected from a nearby park to serve as a control group. The livers of these ducks were analyzed for the specified heavy metals. Results of the analysis are reported in appendices A through D. Sample numbers are identified in appendix E.

In a study such as this it is important to know the history and exposure times of the ducks. Seven of the ducks collected from the CIDA were wild shovelers. Observations prior to collection indicate that the minimum exposure time of the shovelers to the contaminated sediments of the disposal area was 28 days.

Twelve wild mallards were collected at the disposal area in early summer. Ages of these ducks ranged from approximately 30 to 35 days as determined by Bellrose (1976) to a year or more (breeding adults). These 12 ducks were known residents as they were either breeding at the site, pre-flight ducklings or adults in molt and therefore flightless. All collecting was done on the northern half of the disposal area. Therefore, flightless ducks were a mile or more from any source of significant forage other than the invertebrates of the disposal area. The exposure time for the wild mallards was at least 30 days for the ducklings and probably more than 60 days for the adults which were breeding at the site. Adults were collected with young which were at least 30 days old. When this 30 day period is added to the time required for nesting and incubation one can safely assume that these adults had been resident at the site for 60 days or more.

Four captive-raised mallards were placed in a shallow pond at the CIDA at 67 days of age. Unfortunately, 23 days after release, an apparent botulism outbreak began killing wild ducks at the disposal area release pond. At 30 and 31 days after release, the 4 banded experimental birds from the disposal area were recovered either dead or dying from apparent botulism poisoning (Bellrose, 1976). Those that were already dead were relatively "fresh" as they had died within 12 hours of collection (the site was visited every 12 hours during this critical period). The one duckling that was still alive was killed by cervical dislocation. The effects of the botulism on the metal concentrations are unknown. However, Bellrose (1976) indicates that waterfowl which die of the botulism toxin expire very quickly and with no apparent weight loss. The exposure time of these ducklings to the trace metals at CIDA was 30 to 31 days.

A group of six mallards was placed in a lake at Northwest River Park to serve as a control. After 38 days of exposure to that environment the six control ducks were collected at the park release site.

Exposure times of 30, 60, and 90 days and longer are commonly used in feeding experiments involving heavy metal uptake. Accumulated levels of metals are generally higher after longer exposure times (White and Finley, 1978; White and Dieter, 1978; White, Finley, and Ferrell, 1978; Cain and Pafford, 1981); however, 30 days is sufficient to reflect elevated levels in tissues if present and biologically available. Significantly elevated metal levels (up to 300 times the control levels) and associated histologic and physiologic impacts can occur in ducks after only 30 days of exposure (White and Finley, 1978; White and Dieter, 1978; White, Finley, and Ferrell, 1978; Cain and Pafford, 1981). Although longer exposure times would have been desirable, the minimum exposure times of 28 to 50 days for the disposal area and park ducks is believed to be sufficient to detect any increase in availability of heavy metals.

The mean metal values for the three groups of experimental ducks collected for this study were statistically compared to the mean values found in the literature and to control values. Calculations of t-statistics for each pair of means were performed and were compared to the calculated critical value of t for each alpha available in the tables (.001, .01, .02, .05, .1). Since the test was to determine not simply whether the means were different, but whether the means of the samples in the current work were in fact less than the means from the literature, the alpha levels may be validly reported at half the table value. They are so reported in Table II. In all cases the means for the current study were significantly less than the comparable literature values at $p < .01$. In many cases, significance was at $p < .001$.

To evaluate actual use of the disposal site by peregrine falcons, 10 local ornithologists (both amateur and professional) were queried. All reported observing peregrines at the site and generally believed the disposal site to be an important wintering habitat and migratory stop for peregrines. Six ornithologists responded in writing to a questionnaire. For these six respondents, the mean number of years of observation at the site was 12.1 per respondent and the mean for the number of trips to CIDA was 143.5 per respondent. A total of 99 peregrine sightings was reported with a mean of 16.5 sightings per respondent. Therefore, 11.5% of the trips resulted in a peregrine observation (Table III).

DISCUSSION

The peregrine is a large, nearly cosmopolitan, falcon. The species nests on every continent, except Antarctica, and on many oceanic islands. Depending on the subspecies, individuals may range in weight from 16 ounces (454g) to a maximum of around 53 ounces (1502g) for females of the largest races. Peregrines feed almost exclusively on birds which are captured in the air, often after extraordinary aerial pursuits. Peregrines are, however, opportunistic in the types of birds on which they prey. Their prey range in size from small passerines of 1/3 ounce (10g) to waterfowl weighing 4.5 pounds (2041g). More typically, prey weights range from 3/4 of an ounce (19g) to 36 ounces (1020g). When available, the rock dove (Columba livia) seems to be a preferred food species and often represents a major part of the peregrine's diet (Hickey, 1969; Cade, 1982).

Although peregrines sometimes nest in trees, on the ground, or on man-made structures such as bridges and buildings; high sheer cliffs are by far the most important nest site for the species, (Hickey, 1969; Cade, 1982). In describing peregrine falcon nest sites, Hickey introduced the concept of a particular site being an "ecological magnet". He considered such sites to be highly attractive to breeding falcons. This attractiveness was attributed to the physical environment at the site, primarily the height of the nest cliff (Hickey, 1969).

This concept of a particular site being disproportionately attractive to peregrines also extends to areas visited during migration as well as to wintering sites (Cade, personal communication). In this light, Craney Island might be considered an example of Hickey's "ecological magnet" for migrating and wintering peregrines. Again, it is probably the physical environment that makes it so attractive to the falcons. Peregrines prefer landscape of open expanse (Cade, 1982). The extensive area of uninterrupted flats of the disposal site provides an ideal habitat in this respect. Discharge from hydraulic dredging operations and/or rain water keeps large areas of these flats covered by shallow standing water. Consequently, the site often attracts very large concentrations of wintering and migrating waterfowl and shorebirds and almost always supports a substantial number of these birds (personal observations; Laist, 1974). For the purpose of this study, "shorebirds" refers to members of the families Charadriidae, Scolopacidae and

Recurvirostridae. "Waterfowl" refers primarily to the dabbling ducks, subfamily Anatinae.

Many of the shallow water ponds support a thriving macro-invertebrate community. The bug *Trichocorixa verticalis*, a water boatman, and the amphipod *Orchestia platensis* were both found to be abundant in the shallow waters of the disposal site by Laist (1974). For the present study, ponds were randomly sampled for macro-invertebrates with a small mesh dip net. Individual ponds had either high concentrations of invertebrates or almost none at all. In the ponds with high concentrations more than 1000 of these invertebrates could regularly be collected with a single sweep of the net. No difference was noted in the numbers collected in cold weather versus warm weather samples. This was probably due to the relatively high daytime temperatures of the very shallow ponds which allowed considerable invertebrate activity even during the winter months. Water boatmen and amphipods made up virtually 100% of the invertebrate biomass collected from the ponds during the present study.

Waterfowl and shorebirds congregated and appeared to be foraging in and around those ponds which supported large invertebrate populations. Comparatively little bird activity was observed around ponds with low invertebrate populations. Crop analysis of five of the shovelers collected at the site revealed that they were foraging on macro-invertebrates. The crop of one shoveler was empty. Crop content consisted exclusively of water boatmen and amphipods. Shorebirds also make substantial use of these invertebrate types (Bent, 1927). This information suggests that the waterfowl and shorebirds of the disposal area make significant use of the invertebrates there as a forage base.

The concentration of waterfowl and shorebird species provide an ideal prey base for peregrine falcons (Bent, 1938; Sherrod, 1978; Cade, 1982). This prey base, coupled with the open expanse of the site which is required for the peregrine's foraging strategy, account for the disposal site's attractiveness to the falcons.

Questionnaire results further indicate that the disposal site represents an "ecological magnet" to peregrines. Peregrine-prey interactions reported by questionnaire respondents involved primarily waterfowl and shorebirds, though gulls were involved to a lesser extent. One respondent reported capturing four individual peregrines for the purpose of banding. There were reports of two different hacked Peregrines (Tom Nichols and Robert Anderson, personal communications). Hacking is the process by which captive-raised peregrines are released into the wild for the purpose of reestablishing a population (Barclay, 1980; Gabler, 1983). More than 100 peregrines have been so released in Virginia since 1978 which has apparently resulted in establishing five known breeding pairs of falcons in the Tidewater area by 1987 (Mitchell Byrd, personal communications). At least one pair of peregrines has been known to breed at a site on the James River just 22 miles (35.4 kilometers) up river from CIDA (Mitchell Byrd, personal communications). Therefore, there appears to be a potential for peregrine falcon use of the disposal area by two or more different populations of falcons (residents and migrants) and at all times of the year.

The above discussion suggests a food chain existing at the CIDA with invertebrates as primary consumers, shorebirds and waterfowl occupying an intermediate trophic level and peregrine falcons at the top. With highly contaminated sediments as a major component of the physical environment for this food chain, the potential exists for bio-accumulation of contaminants.

Environmental contaminants have had major impacts on peregrine populations in the past. It was the pesticide DDT which, through bio-accumulation, resulted in the peregrine falcon population crash of the 1950's and 1960's in Europe and North America (Hickey, 1969). It has been described as "one of the most remarkable recent events in environmental biology" (Hickey, 1969).

Like DDT, heavy metals have been shown to produce toxic effects in birds. These include poor reproductive success (Finley and Stendell, 1978), anemia and reduced growth rates (Freeland and Cousins, 1973; Richardson, et al, 1974), other physiological disfunctions, and death at high levels of exposure (Cain and Pafford, 1981; Ling and Leach, 1979). Like DDT and many other environmental contaminants, heavy metals can be bio-accumulated in the food chain (Hutchinson, et al, 1975; Kneip, et al, 1974; DiGuilio, 1982). Therefore, a potential appears to exist for bio-accumulation of heavy metals through the aquatic ecosystem of CIDA which could adversely impact the peregrine falcon. The bio-accumulation process is described by Odum (1975). In this process, the contaminants known to be in the sediment (Table IV) would be accumulated by the phyto- and zoo-plankton which occur in the ponds. These provide forage for the known invertebrate communities which in turn provide forage for waterfowl and shorebirds. With each successive trophic level magnifying the accumulated metals, the waterfowl and shorebirds could be carrying greatly elevated levels. Peregrines foraging on these waterbirds could bio-accumulate even greater levels resulting in heavy metal poisoning.

Even though the sediments within the disposal area are known to be highly contaminated with heavy metals, the data gathered for this study suggest that elevated levels of these metals do not appear to be reaching the trophic level of secondary consumers such as waterfowl. The reason for this is unknown and was not intended to be addressed by this investigation.

The levels of metal contamination (of the specified metals) in all three groups of experimental ducks from the disposal area (wild shovelers, wild resident mallards and study mallards) were significantly lower than those metal levels in Maryland canvasback ducks (Aythya valisineria), (White, et al, 1979), Delaware Bay ruddy ducks (Oxyura jamaicensis) (White and Kaiser, 1976) and in urban rock dove (Columba livia) from London (Table V). The suspected source of metals in the London rock dove are sources common to any urban area. Lead anti-knock agents in gasoline and automobile tire residue are some of these urban sources (Hutton and Goodman, 1980). This study is therefore applicable to the urban areas in the vicinity of the disposal site.

Metal values from Chesapeake Bay waterfowl (more than half were puddle ducks) (DiGuilio, 1982), Texas avocets

(Recurvirostra americana) from a confined dredge spoil site (White and Cromartie, 1985), and Texas shorebirds from an industrialized estuarine area (White, et al, 1980) were also available for comparison to present study values (Table V). No statistical significance can be assigned to the differences between the values in the present study and the values in the three later papers because these references did not publish sufficient statistical information with their data. However, the metal values in these latter papers seem to be comparable to those in the three former references whose statistical tests produced highly significant results (Table II).

A t-test was performed to determine if the metal values from the control group (from the park) were significantly less than the values from the three experimental groups (from CIDA). Of the twelve pairs of means tested (4 metals x 3 experimental groups) seven were found to be not significant at $p > .005$, three were found to be marginally significant at $p < .025$ and only two were found to be significantly less than experimental values at $p < .005$ (Table II).

Although there were some significant differences in individual metal values between CIDA ducks and park ducks, the overall differences in these values, when taken as a group, were small as compared to the overall differences in metal values between CIDA ducks and those from the literature. Thus, the CIDA and the park (and areas like the park) appear to be similar in that they both represent a low potential as a source of heavy metal contamination relative to the estuarine and urban habitats used by the areas' peregrines.

Metal levels indicated in Table V are below those shown to be associated with the previously mentioned adverse histologic and physiologic impacts in birds. In many cases Table V values are orders of magnitude below levels of adverse impacts. Tissue metal levels (ppm/dry weight) shown to be associated with adverse impacts for lead are > 29 (Pattee, et al, 1981), for zinc, > 300 (Gasaway and Buss, 1972) and for cadmium, > 160 (White, Finley and Ferrell, 1978). The above discussion is intended to suggest only general metal levels in tissues at which one might expect adverse impacts to occur in birds.

In a study of heavy metal uptake in shorebirds and waterfowl using spoil sites which serve an industrialized Texas harbor, no significant difference was found in metal values in birds collected from the spoil sites and those collected from natural, non-spoil areas (White and Cromartie, 1985). The levels of metal contamination at the Texas spoil sites were from 3 to over 20 times greater than those levels known to be in CIDA sediments (Table IV). Still no elevated metal levels were detected in birds collected there.

The data and previous discussion suggest that the levels of Pb, Zn, Cu and Cd which are available from the Craney Island Disposal Area to peregrine falcons are no greater than levels which are available to peregrines in their typical estuarine or urban wintering areas in the eastern United States or to any resident peregrine population which might be established in the Tidewater area of the state by the aforementioned reintroduction efforts. Moreover, it appears, that a peregrine foraging on Norfolk pigeons or Chesapeake Bay waterfowl may well be exposed to much higher levels of metals than a peregrine feeding on waterfowl and shorebirds from the Craney Island Disposal Area. The data further suggest that non-industrialized sites such as the forested and agricultural area surrounding Northwest River Park may represent a somewhat lesser source of metal contamination than does the disposal area.

TABLE I

METAL VALUES IN ELIZABETH RIVER AND CHESAPEAKE BAY SEDIMENTS AND WITHIN THE EARTH'S CRUST (EPA, 1976)

	Elizabeth River	Chesapeake Bay	Earth's Crust (Range)
Pb mg/Kg	91	27	7-20
Zn mg/Kg	379	128	16-95
Cu mg/Kg	65.1	6.4	4-55
Cd mg/Kg	3.3	<1	.05-.30

TABLE II

TABLE OF PROBABILITY VALUES FOR THE TEST OF WHETHER CURRENT STUDY VALUES ARE SIGNIFICANTLY LESS THAN COMPARABLE LITERATURE VALUES

		Chesapeake Bay Canvasbacks	Delaware Bay Ruddy Ducks	Urban Rock Doves	Study Mallards from Park (Control)
REFERENCE		White et al. 1979	White and Kaiser 1976	Hutton & Goodman 1980	
PRESENT STUDY SAMPLE	METAL				
Wild	Pb	<.005	<.005	<<.0005	<.025
Shovelers	Zn	<.005	-------	<.005	<.025
From	Cu	<.0005	-------	-------	NS >.05
CIDA	Cd	<.005	<.01	<.01	<.005
Study	Pb	<.0005	<.005	<<.0005	NS >.05
Mallards	Zn	<.005	-------	<.0005	<.005
From	Cu	<.0005	-------	-------	NS >>.05
CIDA	Cd	<.0005	<.005	<.01	NS >>.05
Wild	Pb	<<.0005	<.005	<<.0005	<.025
Mallards	Zn	<.01	-------	<.005	NS >.05
From	Cu	<.0005	-------	-------	NS>>.05
CIDA	Cd	<.0005	<.005	<.005	NS >.05
Study	Pb	<<.0005	<.005	<<.0005	
Mallards	Zn	<<.0005	-------	<.0005	
From	Cu	<.0005	-------	-------	
Park	Cd	<.0005	<.005	<.01	

CIDA = Craney Island Disposal Area

TABLE III

QUESTIONNAIRE RESPONSES REGARDING PEREGRINE FALCON USE OF THE CRANEY ISLAND DISPOSAL AREA (CIDA)

Respondent	Season	# Years Observing at CIDA		Estimated Total # of Visits		Estimated # of Peregrine Sightings
1	Winter	10*		354*		19*
	Spring					
	Summer					
	Fall					
2	Winter	14		20		5
	Spring			10		1
	Summer			10		0
	Fall			15		7
			Sub-Total	55	Sub-Total	13
3	Winter	15		23		5
	Spring			22		0
	Summer			0		0
	Fall			35		15
			Sub-Total	80	Sub-Total	20
4	Winter	16		30		10
	Spring			50		3
	Summer			15		6
	Fall			55		16
			Sub-Total	150	Sub-Total	35
5	Winter	14		40		6
	Spring			40		0
	Summer			80		0
	Fall			40		2
			Sub-Total	200	Sub-Total	8
6	Winter	4		16		4
	Spring			2		0
	Summer			2		0
	Fall			2		0
			Sub-Total	22	Sub-Total	4
	Total	75.6		861		99
		Mean = 12.1		Mean = 143.5		Mean = 16.5

*These are actual numbers from field records and not estimates. Seasonal breakdown was not provided.

TABLE IV

LEVELS OF SPECIFIC METALS IN THE SEDIMENTS AT THE CRANEY ISLAND DISPOSAL AREA STUDY SITE AND IN A SIMILAR DREDGE DISPOSAL IMPOUNDMENT AT CORPUS CHRISTI, TEXAS

(PPM/DRY WEIGHT)

	Craney Island Disposal Area (Alden, et al, 1984) N = 21	Corpus Christi, Texas (White and Cromartie, 1985) N = 3
Pb	49.0 (a) +.966 (b)	145 110-171 (c)
Zn	211.9 +7.35	2498 973-6911
Cu	38.1 +.888	N/AV (d)
Cd	1.0 +.052	22.1 7.96 - 58.7

(a) Mean of values
(b) Standard deviation
(c) Range of values
(d) Not available

TABLE V

HEAVY METAL CONCENTRATIONS IN THE LIVERS OF WATERBIRDS AND ROCK DOVE

(PPM-DRY WEIGHT)

	Wild Shovelers From CIDA N = 7(a)	Study Mallards From CIDA N = 4	Wild Mallards From CIDA N = 12	Study Mallards From Park N = 6	Chesapeake (1) Bay waterfowl N = 773	Maryland (2) Canvasbacks N = 29 N = 84 for Pb	Delaware (3) Bay Ruddy Ducks N = 8	Texas (4) Avocets N = 10	Texas (5) Shorebirds N = 75	Urban (6) Rock Dove N = 53 for Pb N = 15 for Zn, Cd
Pb	.20(b) ± .16(c)	.07 ±.02	.04 ±.03	.02 ±.01	6.6 <0.5-18(d)	.41 *	1.03 ±.493	2.3 ND-16.6(f)	1.02 .14-84	21.6 ±1.95
Zn	42 ±7.1	51 ±29	43 ±15	17 ±11	141 103-197	120 *	N/AV (e)	91.5 53-136	N/AV	238.6 ±36.2
Cu	3.0 ±2.8	4.1 ±4.5	2.5 ±1.3	2.4 ±1.2	69 194-262	174 *	N/AV	N/AV	N/AV	N/AV
Cd	.42 ±.19	.07 ±.02	.13 ±.11	.13 ±.08	1.66 .64-5.47	1.74 *	1.79 ±1.24	2.06 .88-4.72	N/AV	9.48 ±3.15

(a) Number of samples analyzed in each group
(b) Mean of values
(c) Numbers preceded by "±" represent standard deviation
(d) Range of values
(e) N/AV = Not available

(*) Standard deviation cannot be calculated from original wet weight data

(1) (DiGuilio, 1982)
(2) (White, 1979)
(3) (White, 1976)
(4) (White, 1985)
(5) (White, 1980)
(6) (Hutton, 1980)

CIDA = Craney Island Disposal Area

APPENDIX A

TABLE OF DRY WEIGHT METAL CONCENTRATION FOR LEAD
SHOWING DATA AND FORMULA USED IN DETERMINATION

SAMPLE	MILLILITERS OF SUPERNATANT	MEASUREMENT OF SPIKE/MM	DILUTION FACTOR	SLOPE	GRAMS OF SAMPLE DRY WT.	DRY WEIGHT PPM
1	20	18.5	10	4.7	4.9	.15
2	20	8	10	4.7	3.0	.11
3	20	5.5	10	4.7	1.9	.12
4	20	14.5	10	4.7	4.7	.13
5	20	54	10	4.7	4.3	.53
6	20	8	10	4.7	5.5	.06
7	20	27	10	4.7	4.1	.28
8	20	26.5	1	4.7	4.8	.02
9	20	8.5	10	4.7	3.0	.11
10	20	35	1	4.7	3.5	.04
11	20	33	1	4.7	3.3	.04
12	20	8.5	10	4.7	4.0	.08
13	20	15.5	1	4.7	3.5	.01
14	20	39	1	4.7	3.5	.04
15	20	9	10	4.7	3.4	.11
16	20	7	10	4.7	3.3	.08
17	20	10.5	10	4.7	6.6	.06
18	20	22.5	1	4.7	5.5	.01
19	20	27	1	4.7	3.5	.03
20	20	40	1	4.7	3.9	.04
21	20	19	1	4.7	6.0	.01
22	20	18.5	1	4.7	6.5	.01
23	20	14	1	4.7	7.3	.00
24	20	35.5	1	4.7	7.6	.01
25	20	32	1	4.7	5.7	.02
26	25	6	10	4.7	5.3	.06
27	20	26.5	1	4.7	4.2	.02
28	20	15	1	4.7	5.9	.01
29	20	27	1	4.7	4.8	.02

Formula:

$$\frac{\text{Supernatant volume} \times \text{AA sample peak in mm} \times \text{dilution factor}}{\text{slope}^{*} \times \text{sample weight in grams} \times 1000^{**}} = \text{PPM value}$$

*Slope value is determined by the slope of the line created when the PPM values of standard samples of known concentrations are plotted against the peak heights (spectrophotometer sample peaks measures in mm's) of these standard samples.

**Converts ppb value as determined by AA equipment to ppm value.

APPENDIX B

TABLE OF DRY WEIGHT METAL CONCENTRATION
FOR ZINC SHOWING DATA AND FORMULA USED IN DETERMINATION

SAMPLE	MILLILITERS OF SUPERNATANT	MEASUREMENT OF SPIKE/MM	DILUTION FACTOR	SLOPE	GRAMS OF SAMPLE DRY WT.	DRY WEIGHT PPM
1	20	9	10	10.1	4.9	36
2	20	8	10	10.1	3.0	51
3	20	7	10	10.1	1.9	74
4	20	4	10	10.1	4.7	16
5	20	10	10	10.1	4.3	46
6	20	8	10	10.1	5.5	28
7	20	10	10	10.1	4.1	48
8	20	14	10	10.1	4.8	57
9	20	8	10	10.1	3.0	51
10	20	7	10	10.1	3.5	39
11	20	6	10	10.1	3.3	35
12	20	4	10	10.1	4.0	19
13	20	5	10	10.1	3.5	28
14	20	12	10	10.1	3.5	67
15	20	14	10	10.1	3.4	81
16	20	7	10	10.1	3.3	41
17	20	5	10	10.1	6.6	14
18	20	13	10	10.1	5.5	46
19	20	14	10	10.1	3.5	79
20	20	8	10	10.1	3.9	41
21	20	5	10	10.1	6.0	16
22	20	3	10	10.1	6.5	9.1
23	20	3	10	10.1	7.3	8.1
24	20	4	10	10.1	7.6	10
25	20	6	10	10.1	5.7	20
26	25	8	10	10.1	5.3	37
27	20	10	10	10.1	4.2	46
28	20	12	10	10.1	5.9	40
29	20	9	10	10.1	4.8	37

Formula:

$$\frac{\text{Supernatant volume x AA sample peak in mm x dilution factor}}{\text{slope* x sample weight in grams}} = \text{PPM value}$$

*Slope value is determined by the slope of the line created when the PPM values of standard samples of known concentrations are plotted against the peak heights (spectrophotometer sample peaks measures in mm's) of these standard samples.

APPENDIX C

TABLE OF DRY WEIGHT METAL CONCENTRATION FOR COPPER
SHOWING DATA AND FORMULA USED IN DETERMINATION

SAMPLE	MILLILITERS OF SUPERNATANT	MEASUREMENT OF SPIKE/MM	DILUTION FACTOR	SLOPE	GRAMS OF SAMPLE DRY WT.	DRY WEIGHT PPM
1	20	4.5	100	2.6	4.9	.69
2	20	20	100	2.6	3.0	7.0
3	20	17	100	2.6	1.9	7.0
4	20	6	100	2.6	4.7	.97
5	20	6	100	2.6	4.3	1.0
6	20	8.5	100	2.6	5.5	1.1
7	20	16	100	2.6	4.1	3.0
8	20	26.5	100	2.6	4.8	4.2
9	20	10	100	2.6	3.0	2.5
10	20	8	100	2.6	3.5	1.7
11	20	3	100	2.6	3.3	.69
12	20	10	100	2.6	4.0	1.9
13	20	13.5	100	2.6	3.5	3.0
14	20	20	100	2.6	3.5	4.3
15	20	46.5	100	2.6	3.4	10
16	20	4.5	100	2.6	3.3	1.0
17	20	5.5	100	2.6	6.6	.63
18	20	7.5	100	2.6	5.5	1.0
19	20	4.5	100	2.6	3.5	.99
20	20	12.5	100	2.6	3.9	2.4
21	20	11	100	2.6	6.0	1.4
22	20	20	100	2.6	6.5	2.3
23	20	36	100	2.6	7.3	3.8
24	20	9	100	2.6	7.6	.91
25	20	15.5	100	2.6	5.7	2.1
26	25	22	100	2.6	5.3	4.0
27	20	24	100	2.6	4.2	4.3
28	20	22.5	100	2.6	5.9	2.9
29	20	28.5	100	2.6	4.8	4.5

Formula:

$$\frac{\text{Supernatant volume} \times \text{AA sample peak in mm} \times \text{dilution factor}}{\text{slope*} \times \text{sample weight in grams} \times 1000\ \text{**}} = \text{PPM value}$$

*Slope value is determined by the slope of the line created when the PPM values of standard samples of known concentrations are plotted against the peak heights (spectrophotometer sample peaks measures in mm's) of these standard samples.

**Converts ppb value as determined by AA equipment to ppm value.

APPENDIX D

TABLE OF DRY WEIGHT METAL CONCENTRATION FOR CADMIUM SHOWING DATA AND FORMULA USED IN DETERMINATION

SAMPLE	MILLILITERS OF SUPERNATANT	MEASUREMENT OF SPIKE/MM	DILUTION FACTOR	SLOPE	GRAMS OF SAMPLE DRY WT.	DRY WEIGHT PPM
1	20	21	20	5	4.9	.33
2	20	22	20	5	3.0	.57
3	20	15	20	5	1.9	.64
4	20	14	20	5	4.7	.23
5	20	22	20	5	4.3	.40
6	20	21	20	5	5.5	.30
7	20	24	20	5	4.1	.47
8	20	26	20	5	4.8	.02
9	20	10	10	5	3.0	.13
10	20	11	10	5	3.5	.12
11	20	7	10	5	3.3	.08
12	20	13	20	5	4.0	.25
13	20	12	10	5	3.5	.13
14	20	7	10	5	3.5	.07
15	20	8	10	5	3.4	.09
16	20	6	10	5	3.3	.07
17	20	7	10	5	6.6	.04
18	20	8	20	5	5.5	.04
19	20	21	1	5	3.5	.02
20	20	25	1	5	3.9	.02
21	20	12	20	5	6.0	.16
22	20	9	10	5	6.5	.05
23	20	5	10	5	7.3	.02
24	20	13	20	5	7.6	.13
25	20	18	20	5	5.7	.25
26	25	8	20	5	5.3	.15
27	20	5	10	5	4.2	.04
28	20	10	20	5	5.9	.13
29	20	7	20	5	4.8	.11

Formula:

$$\frac{\text{Supernatant volume x AA sample peak in mm x dilution factor}}{\text{slope* x sample weight in grams x 1000 **}} = \text{PPM value}$$

*Slope value is determined by the slope of the line created when the PPM values of standard samples of known concentrations are plotted against the peak heights (spectrophotometer sample peaks measures in mm's) of these standard samples.

**Converts ppb value as determined by AA equipment to ppm value.

APPENDIX E

TABLE OF SPECIES AND ORIGINS OF SAMPLE DUCKS COLLECTED FOR THE PRESENT STUDY

SAMPLE NUMBER	SPECIES AND ORIGIN OF SAMPLE
1 through 7 inclusive	Wild shovelers from CIDA
8 through 13 inclusive 18 through 20 inclusive 27 through 29 inclusive	Wild resident mallards from CIDA
14 through 17 inclusive	Study mallards from CIDA
21 through 26 inclusive	Study mallards from Park

BIBLIOGRAPHY

Alden, R.W., R.J. Young, Jr., G.J. Hall and S.S. Jackman. 1984. The environmental quality of sediments in a contained dredged material disposal facility of an industrialized seaport: open ocean disposal alternatives. Old Dominion University Research Foundation. Norfolk, Virginia. pp. 145.

Barclay, J.H. 1980. Release of captive-produced peregrine falcons in the eastern U.S., 1975-1979. Unpublished M.S. thesis. Michigan Technological University. Houghton, Michigan. pp. 118.

Bellrose, F.C. 1976. Ducks, Geese and Swans of North America. Stackpole. Harrisburg, Pennsylvania. pp. 544.

Bent, A.C. 1927. Life Histories of North American Shorebirds, (Part 1). U.S. National Museum Bulletin No. 142. Washington, D.C. pp. 420.

__________ 1927. Life Histories of North American Shorebirds, (Part 2). U.S. National Museum Bulletin No. 146. Washington, D.C. pp. 412.

__________ 1938. Life Histories of North American Birds of Prey, (Part 2). U.S. National Museum Bulletin No. 170. Washington, D.C. pp. 482.

Cade, T.J. 1982. The Falcons of the World. Cornell University Press. Ithaca, New York. pp. 188.

Cain, B.W. and E.A. Pafford. 1981. Effects of dietary nickel on survival and growth of mallard ducklings. Environmental Contamination and Toxicology 10:737-745.

DiGuilio, R.T. 1982. The occurrence and toxicology of heavy metals in Chesapeake Bay waterfowl. Unpublished Phd. dissertation. V.P.I. and State University. Blacksburg, Virginia. pp. 245.

Finley, M.T. and Rey C. Stendell. 1978. Survival and reproductive success of black ducks fed methyl mercury. Environmental Pollution 16:51-64.

Freeland, J.H. and R.J. Cousins. 1973. Effect of dietary cadmium on anemia, iron absorption, and cadmium binding protein in the chick. Nutr. Rep. Int. 8:337-347.

Gabler, J. 1983. The peregrine falcon in Virginia: survey of historic aeries and reintroduction effort. Unpublished M.A. thesis. College of William and Mary in Virginia. pp. 81.

Gasaway, W.C. and I.O. Buss. 1972. Zinc toxicity in the mallard ducks. Journal of Wildlife Management 36:1107-1117.

Hickey, J.J. (ed.). 1969. Peregrine Falcon Populations: Their Biology and Decline. University of Wisconsin Press, Madison. pp. 596.

Hutchinson, T.C., A. Fedorenko, J. Fitchko, A. Kuja, J. Van Loon and J. Lichwa. 1975. Movement and compartmentation of nickel and copper in an aquatic ecosystem. In D. D. Hemphill (ed.): Trace Substances in Environmental Health - IX. University of Missouri Press.

Hutton, M. and G.T. Goodman. 1980. Metal contamination of feral pigeons Columba livia from the London area: part 1 tissue accumulation of lead, cadmium, and zinc. Environmental Pollution (Series A) 22:207-217.

Kneip, T.J., G. Re and T. Hernandez. 1974. Cadmium in an aquatic ecosystem: distribution and effects." In D. D. Hemphill (ed.): Trace Substances in Environmental Health - VIII. University of Missouri Press.

Laist, D.W. 1974. An ecological study of the Craney Island Disposal Area in Hampton Roads, Virginia. Unpublished M.A. thesis. Old Dominion University. pp. 85.

Ling, J.R. and R.M. Leach, Jr. 1979. Studies on nickel metabolism: interactions with other mineral elements. Poultry Science 58:591.

Odum, E.P. 1975. Ecology. Holt, Rinehart and Winston. New York. pp. 244.

Palermo, M.R., F. Douglas Shields and D.F. Hayes. 1981. Development of a management plan for Craney Island Disposal Area. Technical Report EL-1-11. U.S. Army Corps of Engineers. Vicksburg, Miss. pp. 170.

Pattee, O.H., S.N. Wiemeyer, B.M. Mulhern, L. Sileo and J. W. Carpenter. 1981. Experimental lead-shot poisoning in bald eagles. Journal of Wildlife Management 45:806-810.

Richardson, M.E., M.R. Spivey Fox and B.E. Fry. 1974. Pathological changes produced in Japanese quail by ingestion of cadmium. Journal of Nutrition 104:384-403.

Sherrod, S.K. 1978. Diets of North American falconiformes. Raptor Research 12:49-121.

Sokal, R.R. and F. James Rolfe. 1969. Biometry. W. H. Freeman and Co. pp. 775.

U.S. Environmental Protection Agency. 1976. Distribution of metals in Elizabeth River sediments. Tech. Report No. 61. Annapolis Science Center. Annapolis, MD.

Virginia State Water Control Board. 1984. Background and problem assessment report for the Elizabeth River. Information Bulletin 557: 11-24.

White, D.H. and E. Cromartie. 1985. Bird use and heavy metal accumulation in waterbirds at dredge disposal impoundments, Corpus Christi, Texas. Bulletin of Environmental Contamination and Toxicology 34:295-300.

__________ and M.P. Dieter. 1978. Effects of dietary vanadium in mallard ducks. Journal of Toxicology and Environmental Research 4:43-50.

__________ and M.T. Finley. 1978. Uptake and retention of dietary cadmium in mallard ducks. Environmental Research 17:53-59.

____________, M.T. Finley and J.T. Ferrell. 1978. Histopathologic effects of dietary cadmium on kidney and testes of mallard ducks. Journal of Toxicology and Environmental Research 4:551-558.

____________ and T.E. Kaiser. 1976. Residues of organochlorines and heavy metals in ruddy ducks from the Delaware River, 1973. Pesticides Monitoring Journal 9(4):155-156.

____________, K.A. King and R.M. Prouty. 1980. Significance of organochlorine and heavy metal residues in wintering shorebirds at Corpus Christi, Texas 1976-77. Pesticides Monitoring Journal 14(2):58-63.

____________, R.C. Stendell and B.M. Mulhern. 1979. Relations of wintering canvasbacks to environmental pollutants - Chesapeake Bay, Maryland. Wilson Bulletin 91(2):279-287.

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